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(71) Applicant: AER ENERGY RESOURCES, INC. [US/US]; Suite 250, 1500 Wilson Way, Smyrna, GA 30082 (US).

(72) Inventors: PEDICINI, Christopher, S.; 1040 Marvin Land Lane, Canton, GA 30062 (US). GRAY, Gary, E.; 1063 Polo Club Drive, Marietta, GA 30064 (US).

(74) Agents: WARREN, Daniel, J. et al.; Jones & Askew, LLP, 37th floor, 191 Peachtree Street, N.E., Atlanta, GA 30303 (US).

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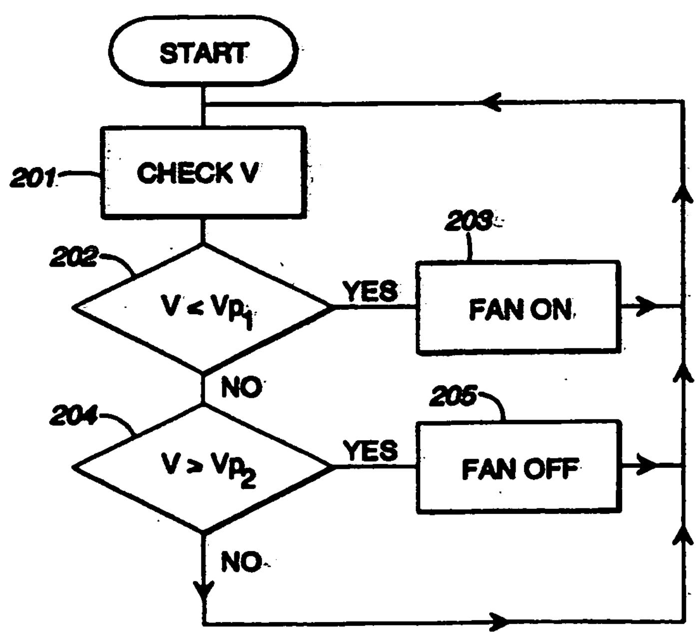
(57) Abstract

An air manager system for a metal-air battery. The system includes a housing for enclosing at least one metal-air cell with an air electrode. The housing also has at least one air inlet opening, at least one air outlet opening, and a fan positioned to force air through the openings when the fan is turned on. These openings are unobstructed and sized to eliminate substantially the air flow through the openings when the fan is turned off. The system also includes fan control means having voltage sensing means to monitor the voltage across the air electrode and to operate the fan when the voltage reaches predetermined levels.



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AIR MANAGER CONTROL USING CELL VOLTAGE AS AUTO-REFERENCE

Technical Field

The present invention relates generally to a battery for electrical power, and more particularly relates to an air-manager system for a metal-air battery.

Background of the Invention

Metal-air battery cells include an air permeable cathode and an anode separated by an aqueous electrolyte. During discharge of a metal-air battery, such as a zinc-air battery, oxygen from the ambient air is converted at the cathode to hydroxide, zinc is oxidized at the anode by the hydroxide, and water and electrons are released to provide electrical energy. Metal-air batteries have a relatively high energy density because the cathode utilizes oxygen from the ambient air as a reactant in the electrochemical reaction, rather than a heavier material such as a metal or a metallic composition. Metal-air battery cells are often arranged in multiple cell battery packs within a common housing to provide a sufficient power output.

A steady supply of oxygen to the air cathodes is necessary to operat the metal-air battery. Some prior systems sweep a continuous flow of new ambient air across the air cathodes at a flow rate sufficient to achieve the desired power

output. Such an arrangement is shown in U.S. Patent No. 4,913,983 to Cheiky. *Cheiky* uses a fan within the battery housing to supply a predetermined flow of ambient air to a pack of metal-air battery cells. Before the battery is turned on, a mechanical air inlet door and an air outlet door are opened and the fan is activated to create the flow of air into, through, and out of the housing. After operation of the battery is complete, the air doors are sealed. The remaining oxygen in the housing slowly discharges the anode until the remaining oxygen is substantially depleted. The residual low power remaining in the cells is disclosed as being sufficient to restart the fan the next time the battery is used.

To ensure that a sufficient amount of oxygen is swept into the housing during use, *Cheiky* discloses a fan control means with a microprocessor to vary the speed of the fan according to pre-determined power output requirements. The greater the power requirement for the particular operation, the greater the fan speed and the greater the air flow across the battery cells. Several predetermined fan speeds are disclosed according to several predetermined power levels of the load. The disclosed load is a computer. The fan speed is therefore varied according to the power requirements of the various functions of the computer. Conversely, many other known air manager systems run the fan continuously when a load is applied.

In addition to the need for a sufficient amount of oxygen, another concern with metal-air batteries is the admission or loss of too much oxygen or other gasses through the housing. For example, one problem with a metal-air battery is that the ambient humidity level can cause the battery to fail. Equilibrium vapor pressure of the metal-air battery results in an equilibrium relative humidity that is typically about 45 percent. If the ambient humidity is greater than the equilibrium humidity within the battery housing, the battery will absorb water from the air through the cathode and fail due to a condition called flooding. Flooding may cause the battery to leak. If the ambient humidity

is less than the equilibrium humidity within the battery housing, the metal-air battery will release water vapor from the electrolyte through the air cathode and fail due to drying out. The art, therefore, has recognized that an ambient air humidity level differing from the humidity level within the battery housing will create a net transfer of water into or out of the battery. These problems are particularly of concern when the battery is not in use, because the humidity tends to either seep into or out of the battery housing over an extended period of time.

Another problem associated with metal-air batteries is the transfer of carbon dioxide or other contaminates from the ambient air into the battery cell. Carbon dioxide tends to neutralize the electrolyte, such as potassium hydroxide. In the past, carbon dioxide absorbing layers have been placed against the exterior cathode surface to trap carbon dioxide. An example of such a system is shown in U.S. Patent No. 4,054,725.

Maintaining a battery cell with proper levels of humidity and excluding carbon dioxide has generally required a sealed battery housing. As discussed above, prior art systems such as that disclosed by *Cheiky* have used a fan of some sort to force ambient air through large openings in the battery housing during use and a sealed air door during non-use. If the air door is not present or not shut during non-use, however, large amounts of ambient air will seep into the housing. This flow of air would cause the humidity and carbon dioxide problems within the housing as discussed above. The oxygen in the ambient air also would cause the cell to discharge, thereby leading to "leakage" current and a reduction in cell efficiency and lifetime.

Even with the use of air doors, however, a certain amount of oxygen and contaminates tend to seep into the cell during non-use. Some leakage current is therefore inevitable. Although the air doors limit this leakage current and the other problems discussed above, the use of the air doors increases the complexity of the battery housing itself and increases the cost and time of manufacture of the overall battery. Another drawback of

a mechanical air door is the fact that the door must be opened and closed, thus adding several more steps to the use of the battery.

The assignee of the present invention is also the owner of application Serial No. 08/544,707, entitled "Diffusion Controlled Air Door," filed October 18, 1995, now U.S. Patent No. ____________, and application Serial No. 08/556,613, entitled "Diffusion Controlled Air Vent and Recirculation Air Manager for a Metal-Air Battery," filed November 13, 1995 (attached hereto as Exhibit A). These references disclose several preferred metal-air battery packs for use with the present invention and are incorporated herein by reference. The air inlet and outlet openings in the housing are sized with a length in the direction through the thickness of the housing being greater than a width in the direction perpendicular to the thickness of the housing. The openings are unobstructed and are sized to eliminate substantially the air flow into the air inlet opening and out of the air outlet opening when the fan is turned off.

The use of the open air door battery housings simplifies the design of the battery as a whole and simplifies the use of the battery. In fact, these battery housing designs allow the metal-air battery to act more like a conventional battery, i.e., the battery is available for the given load without any additional activity such as opening the air doors. The only requirement of these designs is that the fan or other air movement device must be turned on to provide a sufficient flow of oxygen for the cells.

Thus, although these open air door designs are closer to the goal of a metal-air battery that acts as a conventional battery, there is a need in the art for a metal-air battery that is largely self-regulating. Such a metal-air battery would be capable of accommodating both varying loads in an efficient manner and extended periods of inactivity without the need for a mechanical air door or a separate switch for the fan. The lack of a mechanical air door, however, cannot lead to excessive leakage current, flooding, drying out, or the excessive absorption of environmental contaminates.

In sum, the desired metal-air battery would be used in an identical manner to a conventional battery in that all the user needs to do is attach and activate the load. The battery itself would need no separate activation. Further, such a battery would have an energy efficient and quiet air manager system.

Summary of the Invention

The present invention provides an air manager system for a metal-air battery. The system includes a housing for enclosing at least one metal-air cell with an air electrode. The housing also has at least one air inlet opening, at least one air outlet opening, and a fan positioned to force air through the openings when the fan is turned on. These openings are unobstructed and sized to eliminate substantially the air flow through the openings when the fan is turned off. The system also includes fan control means having voltage sensing means to monitor the voltage across the air electrode and to operate the fan when the voltage reaches predetermined levels.

The fan control means turns the fan on when the voltage across the metal-air cell is less than or equal to a predetermined voltage. The fan control means may first determine if a load is present on the metal-air cell before the fan is turned on. Likewise, the fan control means turns the fan off when the voltage across the cell is greater than or equal to a second predetermined voltage. The fan control means, the metal-air cells, and the fan are arranged in a circuit. The voltage sensing means includes a voltage monitor.

Specific embodiments of the present invention include a six volt metal-air battery with five metal-air cells. Such a battery has an energy to load rating of about 230 watt/hours at a drain rate of about 0.5 watt and about 220 watt/hours at a drain rate of about 1.0 watt. The predetermined voltage for turning the fan on is approximately 1.0 volt per cell, while the second predetermined voltage for turning the fan off is approximately 1.1 volt per cell. The voltage monitor turns the fan on when the

voltage across the cell is less than or equal to approximately 1.0 volt per cell. Likewise, the voltage monitor turns the fan off when the voltage across the cell is greater than or equal to approximately 1.1 volt per cell.

The method of the present invention includes the steps of confining at least one metal-air cell with an air electrode within a housing. The housing has a fan, at least one unobstructed air inlet opening, and at least one unobstructed air outlet opening. The method further includes turning the fan on when the voltage across the metal-air cell is less than or equal to a predetermined voltage so as to circulate the air through the housing, and turning the fan off when the voltage across the metal-air cell is greater than or equal to a second predetermined voltage. The method may further include determining whether there is a load on the battery before turning the fan on when the voltage across the air electrode is less than or equal to the predetermined voltage.

Thus, it is an object of the present invention to provide an improved air manager system for a metal-air battery.

It is another object of the present invention to provide a self-regulating air manager system for a metal-air battery.

It is a further object of the present invention to provide an air manager system for a metal-air battery without mechanical air doors.

It is a still further object of the present invention to provide an air manger system for a metal-air battery, with an automatic fan.

It is a still further object of the present invention to provide for an efficient air manager system for a metal-air battery.

It is a still further object of the present invention to provide for an air manager system for a metal-air battery with a long shelf life.

It is a still further object of the present invention to provide a quiet air manager system for a metal-air battery.

Other objects, features and advantages of the present invention will become apparent upon reviewing the following description of preferred embodiments of the invention, when taken in conjunction with the drawings and the appended claims.

Brief Description of the Drawings

Fig. 1 is a cut-away diagrammatic top view of the battery housing embodying the present invention, showing the position of the cells, the fan, and the air openings, in combination with the direction of the flow of air with respect to the housing.

Fig. 2 is a vertical cross sectional view taken along line 2--2 of Fig. 1.

Fig 3 is a diagrammatic pictorial view of a ventilation opening.

Fig. 4 is a schematic view of the voltage sensor circuit.

Fig. 5 is a flow chart showing the operation of the fan based upon the detected voltage.

Fig. 6 is a comparison chart showing the power consumption of an air manager system in a six (6) volts battery with several fan options.

Detailed Description

Referring now in more detail to the drawings, in which like numerals refer to like parts throughout the several views, Figs. 1 - 4 show a metal-air battery **10** embodying the present invention. The metal-air battery **10** may be similar to that disclosed in commonly owned U.S. Patent No. 5,641,588 to Sieminski et al., commonly owned U.S. Patent No. 5,356,729 to Pedicini et al., commonly owned application Serial No. 08/544,707, commonly owned application Serial No. 08/556,613, which are incorporated herein by reference, or other known metal-air battery configurations.

The metal-air battery **10** includes a plurality of metal-air cells **15** enclosed within a housing **20**. The housing **20** isolates the cells **15** from the outside air with the exception of a plurality of ventilation openings **25**. In the embodiment shown in Figs. 1 and 2, a single air inlet opening **30** and a single air outlet opening **35** are utilized. The number of openings **25** is not as important as the aggregate size of the openings **25** in connection with the shape of each opening **25**.

The housing **20** itself may be any type of conventional, substantially air-tight structure. The number of cells **15** within the housing **20** depends upon the nature of the load intended for the battery **10**. The present invention is not dependent upon the configuration of the cells **15** within the housing **20** or the number of cells **15** within the housing **20**. Figs. 1 and 2 therefore show a cut-away view of a metal-air battery housing **20** showing only the essential elements of the present invention, i.e., a housing **20**, one or more cells **15**, and the air openings **25**. Although only two cells **15** are shown in Figs. 1 and 2, it is understood that the number and configuration of the cells **15** depends upon the power requirements for the battery **10**.

A circulating fan **40** is provided for convective air flow both in and out of the housing **20** and to circulate and mix the gasses within the housing **20**. The arrows shown in Fig. 1 represents a typical circulation of gasses into, out of, and within the housing **20** to provide the reactant air to the cells **15**. The capacity of the fan **40** also depends upon the size of the housing **20** and the power demands of the battery **10**. The term "fan" **40** as used herein is intended to mean any device to move air, including a pump.

The fan **40** may be positioned within the housing **20** or adjacent to the housing **20** in communication with one of the openings **25**. If the fan **40** is located within the housing **20**, the ventilation openings **25** are positioned such that the inlet opening **30** and the outlet opening **35** are positioned on opposite sides of

the fan **40**. The only requirement for the positioning within the housing **20** of the fan **40** and the openings **25** is that they are in sufficiently close proximity to each other to create a convective air flow into, through, and out of the housing **20**. The fan **40** may be mounted within or adjacent to the housing **20** in any convenient manner. The fan **40** is generally sealed into place by a gasket **41** or other conventional means to ensure that the low pressure and high pressure sides of the fan **40** are isolated from one another.

As is shown in Fig. 2, the plurality of cells **15** within housing **20** are generally arranged such that a reactant air plenum **50** is positioned under the cells **15**. The air plenum **50** defines an air plenum inlet **55**, an air passageway **60**, and an air plenum outlet **65**. The fan **40** is generally positioned between and isolates the air plenum inlet **55** from the air plenum outlet **65** for efficient air flow through the housing **20**. Examples of air plenum designs are shown in the commonly-owned references cited above. As described above, the present invention is not dependent upon any particular air plenum design.

As is shown in Fig. 3, the ventilation openings **25** are preferably sized such that their length **26**, i.e., the direction through the thickness of the housing **20**, is greater than their width **27**, i.e., the direction perpendicular to the thickness of the housing **20**. By using a large enough ratio between the length **26** and the width **27** for the ventilation openings **25**, it has been found that diffusion of air through the openings **25**, without the assistance of the fan **40**, is substantially eliminated. By "substantially eliminated," it is meant that the rate of diffusion of oxygen or contaminates through the openings **25** is so slow that humidity transfer or drain current is sufficiently small and has little appreciable impact on the efficiency or lifetime of the battery **10**. In sum, the openings **25** are sufficiently long and narrow to provide a barrier to diffusion of gases therethrough when the fan **40** is turned off.

This required ratio between length **26** and width **27** is at least about two to one. These ratios are sufficient to prevent appreciable diffusion through the openings **25** when the fan **40** is turned off while permitting convective air flow therethrough when the fan **40** is turned on. The use of larger ratios between length **26** and width **27** is preferred. Depending upon the nature of the battery **10**, the ratio can be more than 200 to 1.

In use, ambient air is drawn into the air inlet **30** by pull of the fan **40** when the fan **40** is turned on. As is shown by the arrows **45** in Fig. 1, the air is then drawn through the fan **40** and into the air plenum **50**. The air enters the air plenum **50** through air plenum inlet **55**, travels though the pathway **60** to provide a reactant air flow for the cells **15**, and exits via the air plenum outlet **65**. The air is then again drawn into the fan **40** where it either mixes when fresh incoming ambient air or is forced out of the housing **20** via air outlet **35**. When the fan **40** is turned off, the rate of diffusion of air through the openings **25** is reduced to acceptable levels such that a mechanical air door is not required.

As is shown in Figs. 1 and 4, the invention includes a voltage monitor **100** to determine the voltage across the cell **15** or other electrical characteristics and to control the operation of the fan **40**. The voltage monitor **100** can be positioned at any convenient location within or adjacent to the housing **20**. The preferred voltage monitor **100** is a programmable voltage detection or sensing device such as that sold by Maxim Integrated Products under the mark MAX8211 and MAX8212. Depending upon the desired operation of the fan, the voltage monitor **100** can be an analog circuit for a simple "on/off" switch or can incorporate a microprocessor (not shown) for a more complex algorithm. The voltage monitor **100** of Figs. 1 and 4 is an analog circuit.

The voltage monitor **100** determines the voltage across the air electrode **150** of the cell **15**. The air electrode **150** is shown in phantom lines in Fig. 4. Because the zinc

potential within the air electrode **150** of each cell **15** is relatively stable, the air electrode **150** is used to sense the residual oxygen in the cell **15**. As the oxygen within the housing **20** is depleted, the voltage across each air electrode **150** diminishes. Likewise, as the flow of oxygen into the housing **20** increases, the voltage across the air electrode **150** increases.

A preferred air electrode **150** is disclosed in commonly owned U.S. Patent No. 5,569,551 and commonly owned U.S. Patent No. 5,639,568, which are incorporated herein by reference. U.S. Patent No. 5,639,568 discloses a split anode for use with a dual air electrode metal-air cell. Although the use of the invention with a zinc-air battery is disclosed, this invention should be understood as being applicable to other types of metal-air battery cells.

As is shown in Fig. 4, the voltage monitor **100** is connected to the cells **15** in a voltage monitor circuit **105** via a cathode tab **130** and an anode tab **140**. The voltage monitor circuit **105** also includes the fan **40**. All of the cells **15** within the housing **20** are connected in this circuit **105**. The voltage across the cells **15** is continually monitored to ensure that the voltage does not drop below a predetermined voltage V_{p1}. If the voltage does drop to V_{p1}, the fan **40** is turned on and then runs continuously until the voltage is increased to a second predetermined voltage V_{p2}. The fan **40** is then turned off and remains off until the voltage again drops to V_{p1}. The predetermined voltages V_{p1} and V_{p2} are programmable values in the voltage monitor **100**.

The operation of the fan **40** is shown in Fig. 5. The algorithm is an "on/off" type with predetermined values. As is shown in step **201**, the voltage monitor **100** measures the voltage across the air electrode **150**. In step **202**, the voltage monitor **100** determines if the voltage is less than or equal to V_{p1}. If so, the voltage monitor **100** turns on the fan **40** in step **203**. If not, the voltage monitor **100** determines if the voltage is greater than or equal to V_{p2} in step **204**. If so, the voltage monitor **100** turns

off the fan **40** in step **205**. If not, the voltage monitor **100** returns to step **201**. This algorithm may be modified to add an additional step of first checking if a load is present on the battery **10**. If so, the voltage monitor **100** proceeds to step **201** as shown above. If not the fan **40** will remain in the off state.

Alternatively, the speed of the fan **40** maybe altered depending upon the drain rate of the battery **10** as a whole or other electrical parameters. In other words, the voltage monitor **100** can be replaced with other types of conventional electrical sensors known to those practicing in the art. For example, a conventional current sensor, i.e., a sense resistor, could be used. This monitor **100** can set the speed of a variable speed fan **40** as a function of current draw. Instead of the algorithm of Fig. 5, the circuit **105** would contain a conventional microprocessor with a look-up table to compare the determined current draw with a voltage input value for the fan **40**. The input voltage and speed of the fan **40** varies with the determined output current drain. The physical arrangement of the components in this embodiment is the same as that described above.

The operation of the invention is shown in an example using a six (6) volt battery **10**. Such a battery **10** has five (5) metal-air cells **15**, with each cell **15** having an output of about 1.2 volt or slightly higher at about 1 to 4 amps. An up-converter (not shown) also may be used. The housing **20** has openings **25** with a length **26** to width **27** ratio of about four (4) to one (1). The gas flow through the housing when the fan **40** is on is about 15 to about 30 cubic inches per minute for an output current of about 1 amp. When the fan **40** is turned off, the gas flow rate is reduced to about 0 to about 0.03 cubic inches per minute or less, with a leakage current of less than 1 mA. The ratio of output current density with the fan **40** turned on to drain current density with the fan **40** turned off is expected to be at least 100 to 1 in an efficient battery **10**. It is understood that the respective sizes, capacities, densities, flow rates, and other

parameters discussed above are dependent upon the overall size and power requirements of the battery **10**.

The first predetermined voltage V_{p1} under which the voltage should not fall may be about 1.0 volts per cell **15** or about 5.0 volts for the battery **10** as a whole. The fan **40** is turned on when the voltage monitor **100** determines that the voltage of the battery **10** has reached about 1.0 volts per cell **15** or about 5.0 volts for the battery **10** as a whole. The fan **40** then stays on until the voltage of the battery **10** reaches about 1.1 volts per cell **15**, or about 5.5 volts for the battery **10** a whole. The fan **40** remains off until the voltage again reached about 1.0 volts per cell **15** or about 5.0 volts for the battery **10** as a whole.

Assuming the drain rates given above, it would take approximately one month for the six (6) volt battery **10** of the present example to fade from about 1.1 volts per cell **15** to about 1.0 volts per cell **15** to trigger the fan **40** during periods of non-use. The shelf life of the battery **10** would be at least several years. The battery **10** would be immediately ready for use without the need for any independent activation of the battery **10** such as by turning on the fan **40** or by opening a mechanical air door. Rather, the battery **40** is ready for use. The activation of a load on the battery **10** will cause the voltage across the cells **15** to drop as the oxygen within the housing **20** is consumed. This voltage drop will activate the fan **40** until the proper amount of oxygen is introduced into the housing **20** and the proper voltage is restored.

In addition to the present invention being self-regulating, the present invention also provides an energy efficient air manager system. The efficiency of the battery **10** as a whole is increased because the running of the fan **40** is minimized. Fig. 6 compares the energy to load ratio **300** of the present invention in terms of the energy to load ratio **310** of a battery without a fan and with the energy to load ratio **320** of a fan running constantly at various drain rates. As described above, most air manager systems either run the fan continuously or employ a variable

speed fan as is described in *Cheiky*. As is shown in Fig. 6, the present invention provides efficiencies of essentially ninety percent (90%) of a air manager system without a fan.

For example, the energy to load ratio **300** of the present invention in a six (6) volts battery is about 235 Wh while the energy to load ratio **310** of an air manager system without a fan is about 250 Wh. The energy to load ratio **320** of an air manager system with a fan running continuously is only about 135 Wh. The pulsing fan operation of the present invention is therefore an improvement of almost 100 Wh as compared to a constantly running fan. The improvement is maintained until drain rates reach about 5 watts. At that point, the fan **40** of the present invention is essentially running continuously.

Although these efficiencies may be possible with the variable speed fan of *Cheiky*, the present invention uses a simple on/off switch rather than the complex, load specific algorithm disclosed therein. In other words, *Cheiky* requires a specific algorithm for each different type of load. The present invention, however, is available to provide power to almost any type of electrical device.

In sum, by pulsing the fan **40** as described herein, several goals are achieved:

1. The life of the battery **10** is maximized from the standpoint of environmental exposure. In other words, only enough oxygen is admitted into the housing **20** as is needed to maintain the predetermined voltages.

2. Power consumption of the fan **40** is minimized as a percentage of the power consumed by the battery **10** as a whole. For example, a fifty percent (50%) duty cycle may be all that is required at low drain rates. This decreases the overhead energy consumed by the battery **10** as a whole.

3. Because the fan **40** runs in a duty cycle, the battery **10** as a whole is quieter than a battery **10** with a continuously running fan **40**.

The present invention therefore can provide a battery **10** with a relatively long shelf life without the need for a mechanical air door or a fan switch. The present invention can function as, for example, a power source of an emergency device than can be automatically activated because there is no need for a separate activation step. More importantly, the present invention provides for an efficient air manager system that minimizes the running of the fan **40** and the energy drain associated with the fan **40**.

It should be understood that the foregoing relates only to preferred embodiments of the present invention, and that numerous changes may be made therein without departing from the spirit and scope of the invention as defined by the following claims.

Claims

We claim:

1. An air manager system for a metal-air battery, comprising:

a housing for enclosing at least one metal-air cell;

said at least one metal-air cell comprising an air electrode;

said housing having at least one air inlet opening and at least one air outlet opening;

a fan positioned to force said air into said air inlet opening and out of said air outlet opening when said fan is turned on;

said openings being unobstructed and said size of said openings substantially eliminating said air flow into said at least one air inlet opening and out of said at least one air outlet opening when said fan is turned off; and

fan control means comprising voltage sensing means to monitor the voltage across said air electrode wherein the operation of said fan is responsive to said fan control means.

2. The air manager system for a metal-air battery of Claim 1, wherein said fan control means turns said fan on when the voltage across said air electrode, as measured by said voltage sensing means, is less than or equal to a predetermined voltage.

3. The air manager system for a metal-air battery of Claim 1, wherein said fan control means turns said fan off when the voltage across said air electrode, as measured by said voltage sensing means, is greater than or equal to a predetermined voltage.

4. The air manager system for a metal-air battery of Claim 1, wherein said voltage sensing means comprises a voltage monitor.

5. The air manager system for a metal-air battery of Claim 1, wherein said air electrode comprises a zinc anode.

6. The air manager system for a metal-air battery of Claim 1, wherein said at least one metal-air cell, said fan, and said fan control means comprise a circuit.

7. The air manager system for a metal-air battery of Claim 1, said metal-air battery comprises a six volt battery with five metal-air cells.

8. The air manager system of Claim 7, wherein said metal-air battery has an energy to load rating of about 230 watt/hours at a drain rate of about 0.5 watt.

9. The air manager system of Claim 7, wherein said metal-air battery has an energy to load rating of about 220 watt/hours at a drain rate of about 1.0 watt.

10. The air manager system for a metal-air battery of Claim 7, wherein said fan control means turns said fan on when the voltage across said air electrode, as measured by said voltage sensing means, is less than or equal to a predetermined voltage and wherein said fan control means turns said fan off when the voltage across said electrode, as measured by said voltage sensing means, is greater than or equal to a second predetermined voltage.

11. The air manager system for a metal-air battery of Claim 10, wherein said predetermined voltage is approximately 1.0 volt per cell.

12. The air manager system for a metal-air battery of Claim 10, wherein said second predetermined voltage is approximately 1.1 volt per cell.

13. A self-regulating air manager system for a metal-air battery, comprising:

a battery housing;

at least one metal-air cell within said housing;

said metal-air cell comprising an air electrode;

a fan positioned within said housing;

said housing comprising at least one air inlet sized to permit the entry of oxygen when said fan is on and to prevent substantially the transfer of gasses when said fan is off;

said housing comprising at least one air outlet sized to permit the exit of gasses when said fan is on and to prevent substantially the transfer of gasses when said fan is off; and

a voltage sensor circuit comprising said fan, said at least one metal-air cell, and a voltage monitor to determine the voltage across said metal-air cell, such that said voltage monitor operates said fan in response to indications of the voltage across said metal-air cell.

14. The self-regulating air manager system for a metal-air battery of Claim 13, wherein said voltage monitor determines if a load is present on said metal-air battery.

15. The self-regulating air manager system for a metal-air battery of Claim 14, wherein said voltage monitor turns said fan on when the voltage across said metal-air cell is less than or equal to a predetermined voltage after said voltage monitor determines that said load is present on said metal-air battery.

16. The self-regulating air manager system for a metal-air battery of Claim 13, wherein said voltage monitor turns said fan on when the voltage across said metal-air cell is less than or equal to a predetermined voltage.

17. The self-regulating air manager system for a metal-air battery of Claim 13, wherein said voltage monitor turns said fan off when the voltage across said metal-air cell is greater than or equal to a second predetermined voltage.

18. The self-regulating air manager system for a metal-air battery of Claim 17, wherein said voltage monitor leaves said fan off until the voltage across said metal-air cell is again less than or equal to said predetermined voltage.

19. A method for controlling air flow in a metal-air battery, comprising the steps of:

confining at least one metal-air cell within a housing, said at least one metal-air cell comprising a air electrode, and said housing comprising a fan therein, at least one unobstructed air inlet opening, and at least one unobstructed air outlet opening;

turning said fan on when the voltage across said air electrode is less than or equal to a predetermined voltage so as to circulate air through said housing; and

turning said fan off when the voltage across said air electrode is greater than or equal to a second predetermined voltage.

20. The method of Claim 19, further including the step of determining whether there is a load on said battery before turning said fan on when the voltage across said air electrode is less than or equal to said predetermined voltage.

21. A apparatus for controlling air flow in a metal-air battery, comprising:

a housing;

said housing comprising a fan therein, at least one unobstructed air inlet opening, and at least one unobstructed air outlet opening;

at least one metal-air cell confined within said housing;

said at least one metal-air cell comprising a air electrode;

means for turning said fan on when the voltage across said air electrode is less than or equal to a predetermined voltage so as to circulate air through said housing; and

means for turning said fan off when the voltage across said air electrode is greater than or equal to a second predetermined voltage.

22. A apparatus for controlling air flow in a metal-air battery, comprising:

a housing;

said housing comprising a fan therein, at least one unobstructed air inlet opening, and at least one unobstructed air outlet opening;

at least one metal-air cell confined within said housing;

means for determining the current draw on said battery; and

means for controlling the speed of said fan in response to said determination of said current draw.

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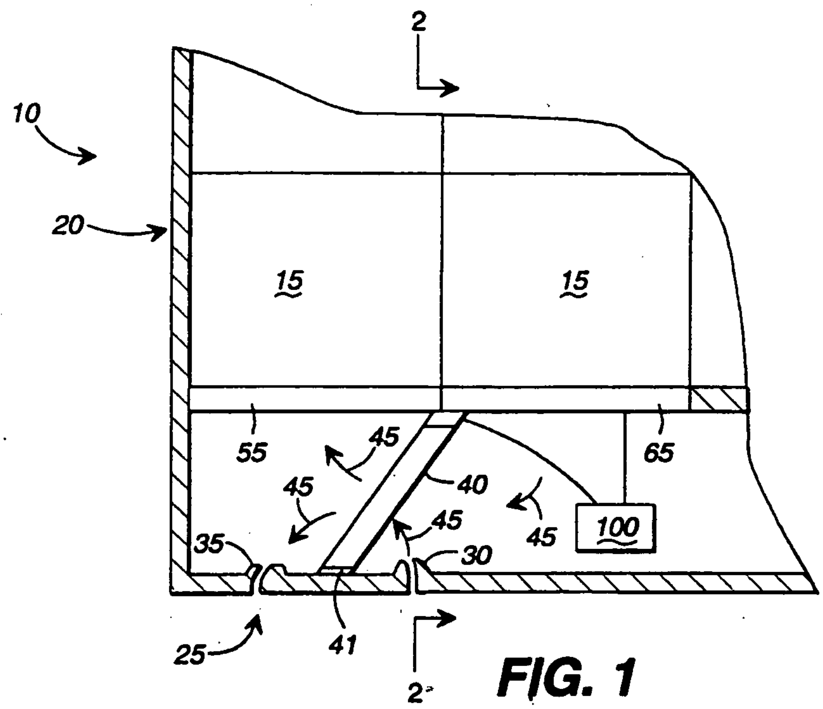


FIG. 1

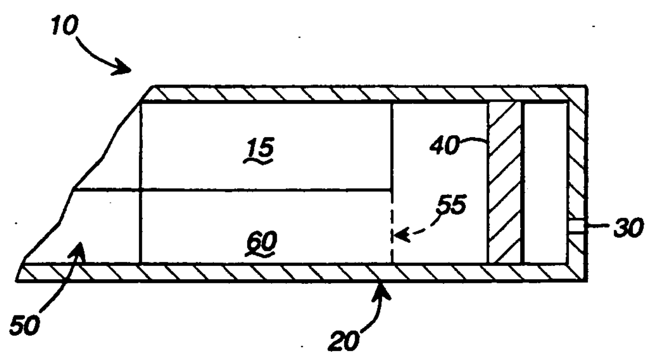
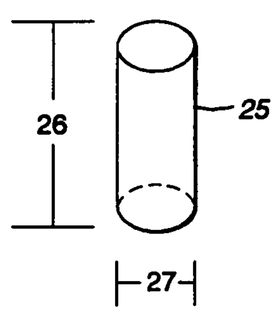


FIG. 2

FIG. 3



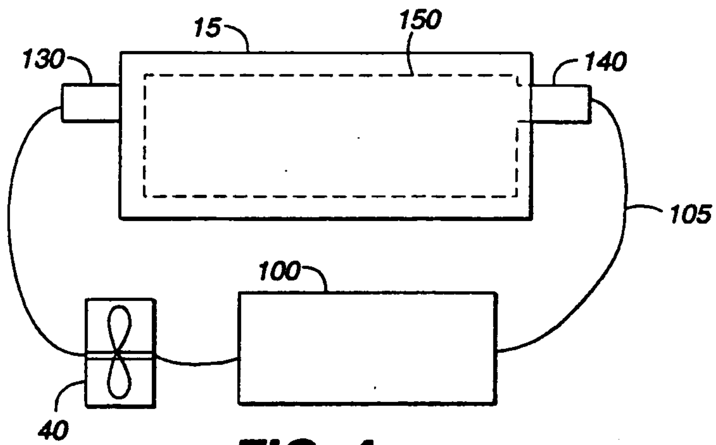

15
150
130
140
105
100
40

FIG. 4

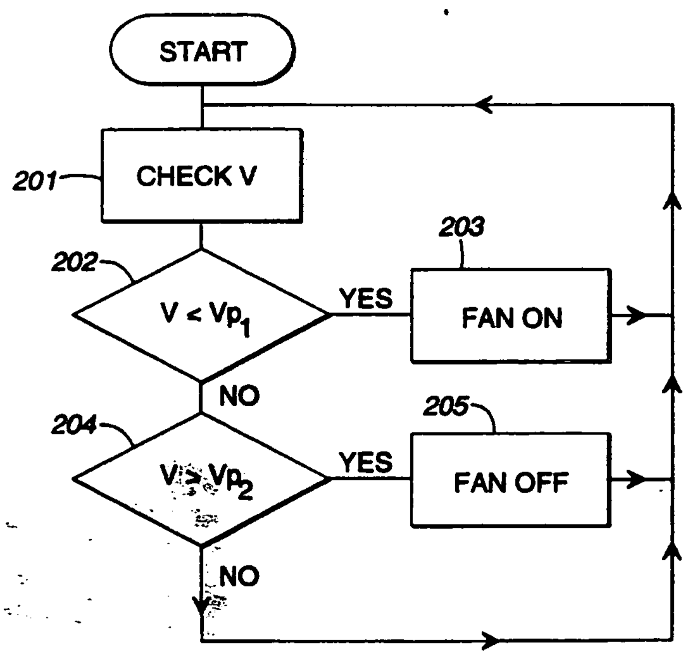

START
CHECK V
201
202
V < Vp1
YES
203
FAN ON
NO
204
205
V > Vp2
YES
FAN OFF
NO

FIG. 5

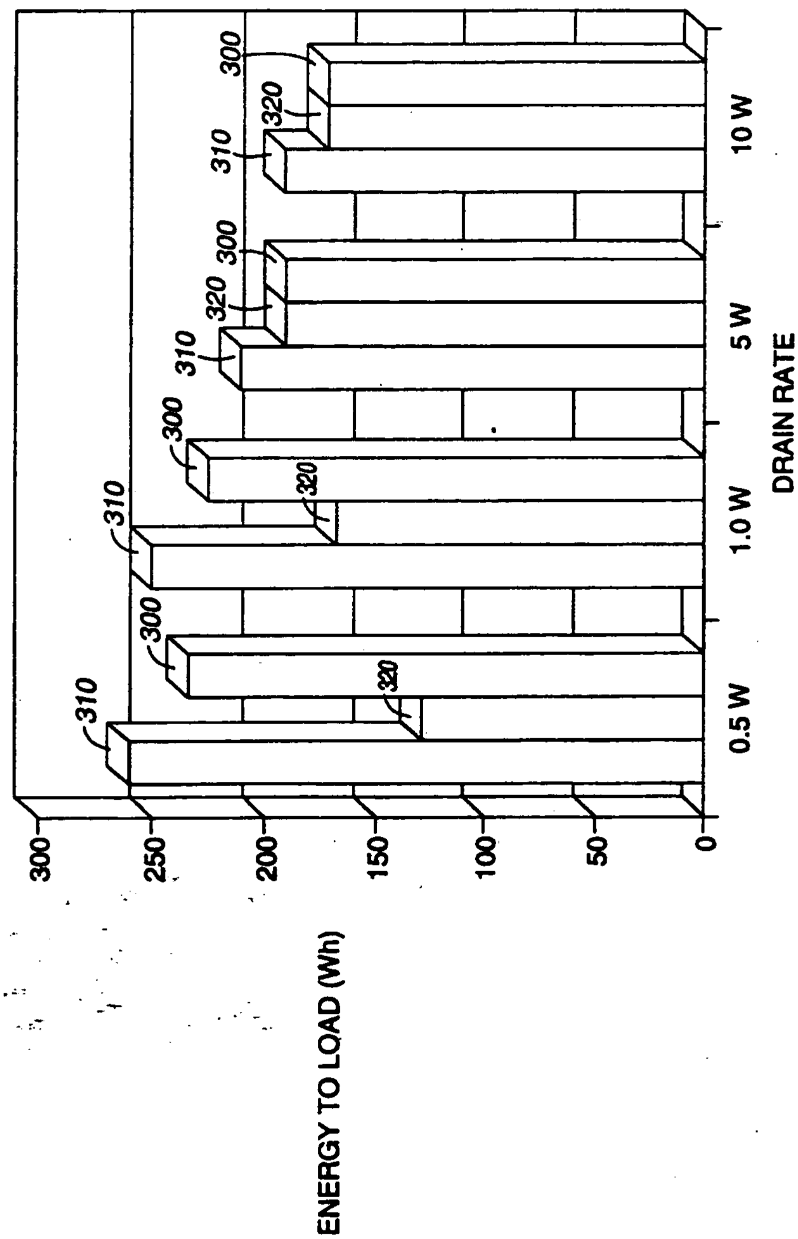

ENERGY TO LOAD (Wh)
300
250
200
150
100
50
0
DRAIN RATE
0.5 W
1.0 W
5 W
10 W
310
320
300

FIG. 6

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 98/20021

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H01M12/06 H01M6/50

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H01M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 97 15090 A (AER ENERGY RESOURCES INC) 24 April 1997 cited in the application see page 6, line 21 - page 9, line 11; claims 1-20	1,13,19, 21,22
Y	PATENT ABSTRACTS OF JAPAN vol. 009, no. 240 (E-345), 26 September 1985 & JP 60 091569 A (TOSHIBA KK), 22 May 1985 see abstract	1,13,19, 21
Y	US 4 913 983 A (CHEIKY MICHAEL C) 3 April 1990 cited in the application	22
A	see column 2, line 19 - column 6, line 13	1-21

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
3 February 1999	12/02/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	De Vos, L

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PCT/US 98/20021

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
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A	US 5 356 729 A (PEDICINI CHRISTOPHER S) 18 October 1994 cited in the application see column 7, line 16 - column 12, line 59	1,21,22

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

P[illegible]al Application No
[illegible]S 98/20021

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			DE	69401130	T	28-05-1997
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			JP	8511896	T	10-12-1996
			US	5560999	A	01-10-1996
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			AT	144653	T	15-11-1996
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			CA	2130559	A	30-09-1993
			DE	69305632	D	28-11-1996
			DE	69305632	T	06-03-1997
			EP	0630527	A	28-12-1994
			JP	2783462	B	06-08-1998
			JP	7508370	T	14-09-1995
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			CA	2163441	A	22-12-1994
			EP	0708992	A	01-05-1996
			JP	2753147	B	18-05-1998
			JP	8510085	T	22-10-1996
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